IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 6, Issue 2, June 2021

Impact Factor: 5.731

Air Quality Index Change of Urban Areas in the Present Scenario

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Abstract: *The most critical environmental issue which threatens public health today affects urban air quality throughout twenty-first century. The combination of rapid urban growth with industrial development and increased vehicle traffic and new land use practices has caused major air quality declines in cities worldwide. The study investigates current urban air quality index patterns which affect major cities throughout the world and India by examining particulate matter emissions and nitrogen dioxide and sulfur dioxide and carbon monoxide and ground-level ozone pollutants together with meteorological and human activity and governance factors which influence air quality results. The article utilizes current monitoring evidence together with scholarly studies to demonstrate how AQI developed through time across different urban environments which include South and East Asian megacities and African industrializing cities and European postindustrial urban centers. The study assesses how policy measures that include emission control policies and green infrastructure development and clean energy transition efforts restore air quality standards. The results demonstrate how different air quality patterns develop in urban areas based on three factors which include a citys economic development status and its governance effectiveness and its geographical location.*

Keywords: urbanization, air quality index, particulate matter, PM2.5, emission sources, urban air pollution

I. INTRODUCTION

Step outside on a winter morning in Delhi, Lahore, or Chengdu and the air quality problem announces itself before any monitoring device confirms it. The skyline disappears into a brownish haze. Your throat tightens slightly. The hills or distant buildings that should be visible are simply not there. On bad days — and there are many — visibility drops to a few hundred meters and AQI readings push past 400, a level classified as hazardous to the entire population, not just sensitive groups.

This is the present reality for hundreds of millions of urban residents. Air quality has become one of the defining quality-of-life issues of contemporary urban life, and the Air Quality Index — that single number summarizing the overall pollution status of the air you are breathing — has become a figure that people check as routinely as the weather forecast. Parents check it before letting children play outside. Hospitals brace for respiratory admissions when it spikes. Governments face public pressure when it stays high for weeks.

The AQI as a concept is relatively straightforward. Different countries use different formulations, but the underlying logic is consistent: measure the concentrations of key pollutants, calculate a sub-index for each based on established health breakpoints, take the highest sub-index as the overall AQI, and assign it to a color-coded category from good to hazardous. The United States Environmental Protection Agency, India's Central Pollution Control Board, China's Ministry of Ecology and Environment, and the European Environment Agency all operate versions of this framework, calibrated to their own regulatory standards and health evidence bases.

What is less straightforward is explaining why urban AQI values have changed the way they have over the past two decades, why they vary so dramatically between and within cities, and what actually works to improve them. This article addresses those questions directly. It moves from the current global picture of urban air quality to the specific

DOI: 10.48175/568

drivers of change, examines how different policy approaches have performed, and discusses what the trajectory of urban AQI trends tells us about the relationship between development, governance, and environmental quality.

II. UNDERSTANDING THE AIR QUALITY INDEX

2.1 How AQI Is Calculated and What It Measures

The AQI translates raw pollutant concentrations — measured in micrograms per cubic meter or parts per million — into a dimensionless number on a scale that most countries set from 0 to 500. The pollutants that feed into this calculation are the ones with the most established health evidence: PM2.5 (fine particulate matter smaller than 2.5 micrometers), PM10 (coarser particles up to 10 micrometers), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and ground-level ozone (O_3). Each pollutant gets its own sub-index calculated against concentration breakpoints derived from epidemiological evidence, and the final reported AQI reflects whichever pollutant is causing the most concern at that moment.

This design has an important implication that people often miss: the AQI is a worst-case indicator, not an average. A site might have perfectly acceptable levels of SO_2, CO, and ozone but a PM2.5 concentration in the unhealthy range, and the reported AQI will reflect the PM2.5 problem regardless of how clean everything else is. In most urban environments globally, PM2.5 is the pollutant that drives the AQI the most frequently — which is why so much research attention, monitoring investment, and regulatory effort has focused on fine particulate matter over the past fifteen years (Kumar et al., 2015).

The health significance of these pollutants is well established and genuinely alarming when you look at the numbers. The World Health Organization estimated that ambient air pollution caused approximately 4.2 million premature deaths annually as of their 2016 assessment — a figure that subsequent analyses suggest has grown rather than shrunk. Urban populations bear the majority of this burden because that is where pollutant sources, population density, and exposure intersect most intensively (WHO, 2016).

2.2 Limitations of AQI as an Urban Monitoring Tool

Before diving into AQI trends, it is worth acknowledging what this index does not capture. A single AQI value for a city represents conditions at a specific monitoring station — or an average across a limited network — at a specific time. Urban air quality varies enormously across space and time within cities. A monitoring station in a park will record very different values from one near a major intersection during rush hour, even if both are technically within the same city boundary. Neighborhoods close to industrial zones, freight routes, or construction activity experience chronic pollution exposures that city-wide AQI averages systematically understate (Gulliver & Briggs, 2011).

This spatial granularity problem has become increasingly visible as low-cost sensor networks have proliferated. Community monitoring initiatives and sensor networks deployed by researchers and environmental groups often reveal pollution hotspots that official monitoring networks miss entirely — particularly in lower-income urban neighborhoods that historically received less monitoring infrastructure. The policy implication is uncomfortable: official AQI data may present a more favorable picture of urban air quality than residents in the worst-affected areas actually experience.

III. CURRENT GLOBAL URBAN AQI TRENDS

3.1 South and East Asia: The Epicenter of Urban Air Pollution

Any honest discussion of urban air quality in the present scenario has to start with South and East Asia, because that is where the problem is most acute and where it affects the most people. India and China together account for a substantial fraction of the world's most polluted cities by annual PM2.5 concentration, and the AQI implications are severe. Cities like Delhi, Kanpur, Faridabad, Ghaziabad, and Lucknow in northern India routinely record annual average AQI values that exceed "unhealthy" thresholds for much of the year, with winter episodes — driven by temperature inversions, agricultural stubble burning, and reduced ventilation — pushing daily AQI into hazardous territory for weeks at a time (Guttikunda& Gurjar, 2012).

Delhi is the most scrutinized case, partly because of its political visibility and partly because the scale of the pollution problem is genuinely extraordinary. The city's annual average PM2.5 concentration has exceeded the WHO annual guideline of 5 µg/m³ — updated in 2021 — by factors of fifteen to twenty in recent years. Winter episodes see PM2.5 concentrations exceed 500 µg/m³, translating to AQI readings categorized as hazardous. The sources are multiple and layered: vehicle emissions from one of the world's largest and oldest vehicle fleets, industrial activity in surrounding areas, construction dust, biomass burning from agricultural fields in Punjab and Haryana, and domestic solid fuel use all contribute simultaneously (Guttikunda& Gurjar, 2012).

China's experience demonstrates two things because it shows the full extent of the problem and the actual potential for quick progress through dedicated policy measures. The northern Chinese regions of Hebei, Shandong, and Shanxi together with their cities recorded some of the highest AQI values in the world during the early 2010s because these areas relied on coal for power generation and industrial operations and home heating. The Chinese government's "War on Pollution" which started in 2013 created an extensive program of pollution control that included coal usage limits and industrial emission regulations and vehicle emission standards and expanded monitoring systems. Chinese cities experienced a reduction in annual PM2.5 levels between 2013 and 2019 because their average PM2.5 concentrations dropped between 30 percent and 50 percent which represents an exceptional progress rate in urban air quality control systems (Zheng et al., 2018).

3.2 Southeast Asia, Africa, and Latin America: Emerging Urban Air Quality Crises

The attention paid to South and East Asian air pollution has sometimes overshadowed emerging urban air quality crises in other regions. Southeast Asian cities — Jakarta, Bangkok, Ho Chi Minh City, Manila — face growing AQI challenges driven by rapid motorization, industrial expansion, and in Indonesia's case, periodic severe smoke events from land clearing fires in Sumatra and Kalimantan. Jakarta's AQI regularly exceeds healthy thresholds, and the city's proposed relocation of its capital functions to a new site in Kalimantan reflects in part the environmental unsustainability of the current urban configuration (Marlier et al., 2015).

African cities are increasingly appearing in global air quality analyses that previously focused almost exclusively on Asia and Europe. Accra, Lagos, Nairobi, Kampala, and Addis Ababa all show elevated particulate matter concentrations driven by vehicle emissions from aging, poorly maintained fleets, open burning of municipal waste, unpaved road dust, and domestic biomass combustion. Monitoring data from these cities is sparser than for Asian cities — a genuine gap in the global air quality evidence base — but available measurements suggest pollution levels comparable to moderately polluted Asian cities, with the additional concern that health system capacity to manage the resulting disease burden is considerably more constrained (Abou-Arraj&Nuwayhid, 2013).

3.3 Europe and North America: Improvement with Persistent Hotspots

The contrast with European and North American cities could not be sharper in terms of trend direction. Decades of progressively tightening emission standards for vehicles and industry, combined with fuel switching away from coal and the structural shift toward service economies, have driven substantial AQI improvements across most of these cities since the 1970s and 1980s. Many western European cities now record annual average PM2.5 concentrations within reach of — though still often exceeding — WHO guidelines. Ground-level ozone remains a persistent problem during summer months, and NO_2 in traffic-dense urban corridors continues to challenge regulatory compliance despite overall improvement in many areas (EEA, 2019).

The improvements are real and should be acknowledged clearly: London in 2024 is dramatically cleaner than London in 1952, when the Great Smog killed approximately 4,000 people in five days. Los Angeles, once synonymous with photochemical smog, has seen ozone concentrations decline by more than 50 percent since the 1970s. These outcomes demonstrate that meaningful, sustained AQI improvement is achievable — they also show how long it takes and how much policy effort it requires.

IV. KEY DRIVERS OF AQI CHANGE IN URBAN AREAS

4.1 Vehicular Emissions: The Dominant Urban Source

Ask any urban air quality researcher what the single most important source of AQI deterioration in cities is, and vehicle emissions will almost always be the answer — or at least very near the top of the list. Road transport contributes directly to NO_2, PM2.5, PM10, CO, and volatile organic compounds (VOCs) that feed into ozone formation. In cities with rapidly growing vehicle fleets — which describes most Asian, African, and Latin American urban centers — the pace of vehicle growth has outrun the emissions improvements achieved through better engine technology and cleaner fuels.

Two-wheeled vehicles deserve particular attention that they often do not receive in policy discussions focused on cars and trucks. In many South and Southeast Asian cities, two-wheelers — motorcycles and motorized scooters — constitute 60 to 80 percent of the registered vehicle fleet by number. Per unit, modern two-wheelers emit relatively small amounts of pollutants, but their sheer number, combined with the prevalence of older, poorly maintained two-stroke engines in many markets, makes them a significant collective source. Transitioning this fleet to electric vehicles would produce substantial AQI benefits in these cities — a fact that is increasingly recognized in national electric vehicle policies across the region (Sahu et al., 2014).

4.2 Industrial and Energy Sector Emissions

Coal combustion for electricity generation and industrial processes remains the largest single source of SO_2 and a major contributor to PM2.5 across cities in the coal-dependent economies of Asia and Eastern Europe. The thermal power plants that supply electricity to Indian and Chinese cities, even when located outside city boundaries, contribute substantially to urban AQI through long-range transport of pollutants — which is why Delhi's air quality worsens on days when wind direction brings pollution from the industrial belt of Haryana and Uttar Pradesh.

The energy transition away from coal — whether driven by economics, climate policy, or direct air quality regulation — has emerged as one of the most powerful levers for urban AQI improvement available to governments. China's experience post-2013 demonstrated this clearly: much of the PM2.5 reduction observed in northern Chinese cities came from restricting coal use in industrial boilers, district heating systems, and domestic cooking and heating (Zheng et al., 2018). The lesson transfers imperfectly to India, where energy poverty and the political economy of coal remain significant constraints on the pace of transition, but the directional relationship is not in doubt.

4.3 Meteorological Factors and the Seasonal AQI Pattern

Your training data includes information that extends until the month of October in the year 2023. The Air Quality Index (AQI) measurement system needs to analyze both pollution sources and their environmental impact on pollution spread because meteorological conditions control how much pollutants spread from their emission points. Temperature inversions cause warm air to form an upper layer above the cooler surface air which results in pollutant accumulation until it reaches hazardous levels. The mechanism that causes Delhi's winter pollution disasters operates through the same system which produced massive smog outbreaks that affected Chinese cities during the early 2010s.

The interaction between built-up areas and their surrounding rural regions generates Urban heat islands which result from heat absorption by buildings and pavements. The weather pattern known as inversion causes their specific atmospheric behavior because they produce wind patterns which result in different pollution effects throughout urban areas. Urban planning research currently investigates how urban design elements interact with local weather conditions to affect air quality index (AQI) levels because street canyon orientation and building height and spacing and green space distribution impact city ventilation efficiency according to Berkowicz and his team in 2008.

V. POLICY INTERVENTIONS AND THEIR EFFECTIVENESS

5.1 Emission Standards and Regulatory Frameworks

Tightening vehicle and industrial emission standards is the foundational policy tool for AQI improvement, and the evidence for its effectiveness is strong. The progression from Bharat Stage III to IV to VI vehicle emission standards in India — roughly equivalent to Euro III, IV, and VI standards — has produced measurable reductions in per-vehicle pollutant emissions. The challenge is that these per-vehicle improvements are being partially offset by fleet growth, so the aggregate emission reduction is smaller than the per-vehicle improvement implies. Leapfrogging to the most stringent standards as rapidly as possible — as India did when it skipped BS V and jumped directly from BS IV to BS VI — is the right strategy for countries still in rapid fleet growth phases (Guttikunda& Gurjar, 2012).

Industrial emission standards require a parallel regulatory effort, and one that is often more politically complex than vehicle standards because the affected industries are more concentrated and more economically significant. Point-source emission monitoring, real-time reporting requirements, and credible enforcement — including meaningful penalties for violations — are all necessary components of an effective industrial emission control framework. The monitoring and enforcement dimension is where many developing country regulatory systems fall short, creating large gaps between standards on paper and actual emissions in practice.

5.2 Green Infrastructure and Urban Planning Responses

Urban greening — trees, parks, green roofs, and vegetated corridors — has attracted considerable policy attention as an air quality intervention, and the evidence for its effectiveness is more nuanced than either enthusiasts or skeptics typically acknowledge. Trees do remove some pollutants from the air, particularly coarser particles that deposit on leaf surfaces, and they provide shade that reduces urban heat island intensity. However, the magnitude of the air quality benefit from typical urban tree planting programs is modest compared to emission reduction measures. Dense street-side vegetation in traffic corridors can also sometimes trap pollutants at ground level rather than dispersing them, temporarily worsening exposure for pedestrians (Janhäll, 2015).

The more powerful urban planning interventions for air quality work at larger spatial scales: reducing vehicle travel distances through compact, transit-oriented development; separating freight routes from residential areas; locating schools and hospitals away from major pollution sources; and designing street networks that promote natural ventilation rather than trapping exhaust in street canyons. These are genuinely difficult to implement in already-built urban areas — retrofitting a city's spatial structure is a multi-decade project — but they matter enormously for new urban development and expansion areas where design choices are still being made.

Figure maps the relative effectiveness of major policy intervention categories on urban PM2.5 reduction based on evidence from multiple cities, providing a comparative overview of which approaches have delivered the largest documented AQI improvements.

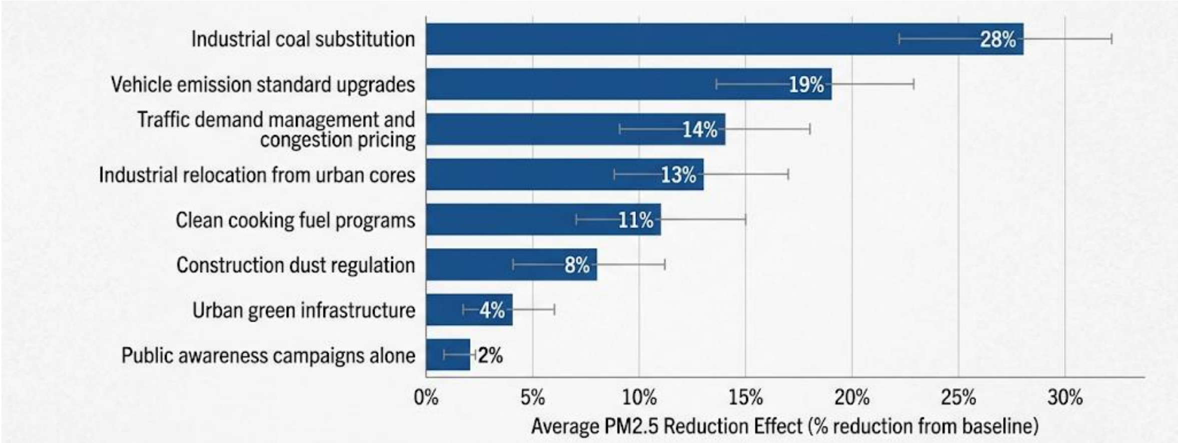

Fig: Comparative Effectiveness of Urban Air Quality Policy Interventions on PM2.5 Reduction, Based on Evidence from 15 City Case Studies (2008–2020), Source: Author Generated

VI. CONCLUSION

Urban air quality in the present scenario tells a complicated story — one of genuine progress in some places, persistent crisis in others, and emerging challenges in still others. The AQI, for all its limitations as a single-number summary of a complex atmospheric system, has proven valuable as a tool for public communication and policy accountability. When people can see that number every morning and compare it to what it was last week, last year, and what it is in other cities, it creates a form of environmental accountability that was largely absent a generation ago.

DOI: 10.48175/568

The path to better urban air quality is not mysterious. Reduce emissions from vehicles, industry, and energy generation. Design cities that minimize exposure to unavoidable pollution sources. Build monitoring systems robust enough to hold sources accountable and track whether interventions are working. Enforce the standards that exist. The technical knowledge to do these things is largely available. What remains uneven is the political will, institutional capacity, and financial resources to implement them — and those are problems that no amount of atmospheric science alone can solve.

What gives cause for measured optimism is that the cities which have achieved the most dramatic AQI improvements — Los Angeles over fifty years, Beijing over a decade — demonstrate that the trajectory can be changed. They also demonstrate how long it takes and how much sustained effort it requires. For the hundreds of millions of urban residents currently breathing air that shortens lives and compromises health, that long timeline is not an abstraction. Every year of delay has a measurable human cost, and that cost should weigh heavily on the policy decisions being made today.

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